V. V. Rumyantsev: "The Equations of Motion of a Rigid Body Containing Hollow Spaces Partially Filled With Liquid", Prikladnaya Matematika i Mekhanika, Vol 18 (1954), pp 719-728.

Zhukovskiy treated the same subject for the case of hollow spaces completely filled with an homogeneous incompressible liquid. The author expands the earlier investigations by including the case of hollow spaces only partially filled with an homogeneous, incompressible, and frictionless liquid, which means that there is also a free surface of the liquid. In the derivation of the equations of motion, based on the Hamilton principle, the following are assumed:

1) The body is rigid.

2) A constant pressure prevails in the areas of the hollow spaces which are not filled with the liquid.

3) The components of motion of the body and of the liquid normal to the boundary surface of the hollow space are equal.

Liquid and body are considered a single mechanical system. The pressure forces transmitted between the liquid and the body at the boundary surfaces are therefore internal forces and are not included in the equations of motion. In all there are four equations. The first equation expresses the theorem of momentum for the forward motion; the second expresses the theorem of momentum for the rotation; the third equation is a Euler equation of motion for the liquid transformed to the co-involved solid system of coordinates; the fourth equation is the continuity condition for the liquid. Generally speaking, the equation system is extremely complicated. It is considerably simplified, however, in a few special cases, for example, when the hollow spaces within the body are completely filled with liquid, or when the body has a fixed axis of rotation, or when certain conditions of symmetry are satisfied for the body or the hollow spaces within it.

Under certain conditions some first integrals of the equations of motion can also be given: an energy integral, insofar as forces effecting the system have a force function, and an impulse integral, insofar as the forces around one of the axes produce no moment. For the case of a symmetrical gyroscope with symmetrical hollow spaces within it, for which the forces produce no moment around the figure axis, the fact that the rotation velocity of the system around the figure axis is constant can be computed as an additional integral.

V. V. Rumyantsev: "On the Stability of the Rotations of a Heavy Solid Body Around a Fixed Point in the S. V. Kovalevskaya Case", Prikladnaya Matematika i Mekhanika, Vol 18 (1954), pp 457-458.

In connection with a completely analogous investigation by Chetayev for the case of a Lagrange gyroscope, the author investigates the stability of the rotations for the case of the Kovalevskaya gyroscope in which the center of gravity lies on an equatorial axis. Following the example of Chetayev, he forms a Liapunov function out of the partial integrals of the equations of perturbed motions and arrives at the desired stability condition because of the demand for definity. This necessary and sufficient condition combines the moment of gravity of the gyroscope with the moment of inertia around the axis of the figure. The motions in respect to both the rotation components and the cosine of direction of the axis of the figure are stable if the condition is satisfied.

N. G. Chetayev: "Concerning the Stability of the Rotations of a Solid Body Around a Fixed Point in the Lagrange Case", Prikladnaya Matematika i Mekhanika, Vol 18 (1954), pp 123-124

The conditions of stability for the Lagrange case are derived for the most part from the Euler gyroscope equations. The author attempts to derive this condition of stability according to the so-called direct method of Liapunov. For this purpose he sets up equations of the perturbed motion

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in respect to the three components of rotation, which are fixed in respect
to a body, and the three cosines of direction of the axis of the figure,
from which four integrals can be given. A Liapunov function can be constructed
from these integrals. Out of the demand for the definition of this function
the known stability condition can be found, which requires for the
momentum component of the gyroscope around the axis of the figure a minimum
value depending on the moment of gravity and the equatorial moment of
inertia.

V. N. Koshlyakov: "Concerning Certain Special Cases of the Integration
of the Dynamic Euler Equations Connected With the Motion of a Gyroscope
in a Medium With Resistance", Prikladnaya Matematika i Mekhanika, Vol 18
(1953), pp 137-148.

When a gyroscope moves in a medium with resistance, corresponding forces
are exerted on it. If these forces have certain mathematical relationships,
the appropriate Euler equations can be integrated. To the already known
cases of this type (calculated by Krutkov and Bulgakov) the author adds a
new one. He first treats a slightly asymmetrical gyroscope for which the
external moments around the main axes of inertia are proportional to the
corresponding components of momentum. The calculation in this case is only
possible thru an expansion in a power series, in which the assumed small
relative asymmetry of the gyroscope is used as a parameter of expansion.
The calculation is carried thru in this case as far as the first approximation.
The result is that the influence of this asymmetry of the gyroscope is
insignificant as long as the asymmetry is actually small.

If the gyroscope is symmetrical, and if the external moments are
similarly disposed, a strict solution of the equations can be given with
the aid of the Bessel function. Theoretically, the solution can also be
given for the case where the external moment is additionally dependent on
the time.

The case, in which the moment around the axis of the figure is assumed to be proportional to the square of the rotation velocity, has a practical significance, since this case occurs when the gyroscope is moving in air. The equations of motion can then be solved in an elementary way only for definite values of the coefficients entering into the equations. Even with a successful solution of the dynamic Euler equations, in all cases investigated thus far there remains the difficulty of computing the Euler angle out of the kinematic Euler equations.

In the last part of the article the author returns to a problem treated by him before in regard to the theory of the artificial horizon and brings up the question of the errors in indication which can arise with a change of the rate of spin of the gyroscope. He is especially interested here in the case where the power which drives the gyro is suddenly cut off and the gyro runs down. If in such a case an exponential drop in the rate of a spin is assumed, a solution can be found with Bessel functions of the zero order. In the case of a hyperbolic drop, on the other hand, cylindrical functions are obtained. In both cases the result of the drop in the rate of spin is a damped motion.

L. I. Tkachev: "Concerning the 84-Minute Period in Systems with Fixed and Free Gyroscopes", Prikladnaya Matematika i Mekhanika, Vol 18 (1949), pp 217-218.

The author shows that the 84-minute period is not exclusively a characteristic of systems in which the gyroscope is pendulous, although until now only such cases have been treated in the literature.

If an artificial horizon is produced in such a way that the gyroscopic couple of a fixed gyroscope is measured and combined with the values of two accelerometers in a computer, it can be shown that this system also has a period of 84 minutes, if the synchronization is unaccelerated.

The same can be shown for a system which has a free gyroscope instead of a fixed gyroscope. The free gyroscope serves actually only as a basis for the two instruments which measure the acceleration components. The

gyroscope in this case has a fixed direction in space independent of the earth's rotation. The horizon indication is a purely mathematical value produced from the integrating device. In this case too, with sporadic perturbations of the indication of the horizon, a period of 84-minutes is obtained.

This article, which is only two pages long, has a purely theoretical significance. No suggestions are given for any practical applications.

G. A. Slomyanskiy: "On the Integration of the Equations of Motion of a Symmetrical Astatic Gyroscope", Prikladnaya Matematika i Mekhanika, Vol 18 (1953), pp 411-422.

The author integrates the equations of motion of a symmetrical, astatic, Cardan mounted gyroscope with the use of a reference system which is rigid in space and conforms to the Cardan suspension. He neglects the mass of the Cardan suspension. Although a few first integrals for the general -- not linearized -- problem can be given, the complete solution is attempted only for three special cases.

A strict solution with the help of elementary functions is possible in the case of the force-free gyroscope. The results obtained cannot be expanded to larger ranges of tilting of the inner Cardan ring, since the influence of the mass of the suspension neglected in the calculation would then become considerable. The "clinch-position" of the Cardan mounted gyroscope, which occurs when the inner ring is rotated 90°, does not appear in these calculations as a singular point.

In the case of a constant external moment around the inner Cardan axis the strict solutions can be given only in integral form. A better approximate solution is obtained when the angle of nutation changes only slightly. In this way generally valid formulas for the general regular precession are obtained, which can still be further simplified for the case of the fast spinning gyroscope.

Finally the solution of the equations of motion is given for the case where a moment around the inner axis depends on the angle of rotation around this axis. In this case also only a first integration is possible, so that the general solution can only be given in integral form.

P. A. Kuz'min: "An Addition to the Steklov Case of the Motion of a Heavy Gyroscope Around a Fixed Point", Prikladnaya Matematika i Mekhanika, Vol 16 (1952), pp 243-245.

The case treated by Steklov in 1899, whereby the motion of an asymmetrical gyroscope, in which the gravity point lies on a main axis of inertia, is considered. By means of a special extension for the gravity moment entering into the Euler equations of motion, a special solution is found for which the three components of the gyroscope rotation can be expressed by the Jacobi elliptical functions.

V. N. Koshlyakov: "Concerning the Error of the Gyroscopic Horizon in Connection With A Variable Self-Motivated Spin of the Gyroscope Rotor", Ingenieur-Rundschau, Vol 6 (1950), pp 185-196.

In the first part of the article the linearized equations for the small deflections of the gyroscope are derived, both for a fixed instrument and for the case of an arbitrary horizontal motion of the supporting frame.

In the second part the differential equations for the special case are investigated, in which a rapid but small change of the spin, and therefore also of the gyroscopic effect, takes place. The calculation is done by two Volterra integral equations of the second order, which are solved by iteration. Expansions in a power series are carried out according to the assumed small change in momentum, and the higher series elements are neglected. The numerical evaluation of the calculations shows that the indicating accuracy of the instrument is practically uninfluenced by

small changes of the rate of spin. Even with a 5% change in the rate of spin, the errors are still smaller than 10 minutes of arc.

In the third part the influence of periodically successive changes in the rate of spin is investigated. The investigations here likewise show that under normal conditions there is no appreciable effect on the accuracy of the instrument. In certain practically unimportant areas resonance phenomena can be produced, such as are known to occur in systems with periodic coefficients.

V. V. Rumyantsev: "On the Equations of Motion of a Solid Body With Hallow Spaces Containing Liquid", Prikladnaya Matematika i Mekhanika, Vol 19 (1955), pp 3-12.

In connection with articles by Poincaire and Chetayev the author sets up the equations of motion for a gyroscope containing arbitrarily formed internal cavities which are completely or partially filled with a homogeneous, incompressible, and frictionless liquid.

The equations are given in three different forms:

1) a form used by Poincare, but expanded to include arbitrarily formed hollow spaces in a system of coordinates which is fixed in respect to a body;

2) an expanded form of the Lagrange equations of motion in a reference system rigid in space;

3) a canonical form used by Chetayev, which can be considered an expansion of the Hamilton equations.

Both conservative and non-conservative forces are considered in the derivation. Solutions or formulations of solutions for the equations of motion are not given.

N. N. Bautin: The Behavior of Dynamical Systems Near the Boundary of the Stability Boundaries, monograph in the series "Modern Problems of Mechanics", State Publishing House for Technical and Theoretical Literature, Moscow-Leningrad (1949)

In this monograph the author shows how in nonlinear systems the question of danger or lack of danger of the stability boundary, produced by a linear treatment of the same system, can be solved. He bases his procedure on earlier investigations of Liapounov and shows that the question of the danger or lack of danger can be decided by the sign of a "Liapounov function".

Among his several examples are two gyroscope problems: a gyro-stabilized single track railroad and a ship stabilized for pitch and roll by gyroscopes. In both cases the gyroscope is used as a stabilizer which produces stabilizing moments directly. The difference between the two systems lies in the fact that the containment of gravity in the gyroscope system for the single-track railroad is negative (center of gratity above the point of suspension), whereas in the case of the ship's gyroscope it is positive (center of gravity below the point of suspension).

In both cases the results of the investigations are plotted without dimensions. With the single-track railroad there are two critical values for the size of the viscous damping around the axis of the frame for every value of the gyroscopic moment. Below the smaller value and above the larger value the system is unstable. The investigation shows, with the help of the Liapounov function, that exceeding the upper boundary is not dangerous, but merely leads to vibrations of limited amplitude; exceeding the lower boundary is dangerous, however, since there is an increase of the amplitudes, and the system changes to another state of equilibrium.

In the case of the ship's gyroscope the lower critical boundary value for the frame-damping drops out, so that the portion of the stability boundary corresponding to the upper value is not dangerous. If this portion of the boundary is exceeded, oscillations will build up, but the extent to which they can build up depends on the degree to which the boundary is exceeded. If the boundary is exceeded only slightly, only very slight

vibrations will be produced. A return to within the boundary will bring
an end to the vibrations. The system is reversible, but exceeding the
boundary at dangerous portions leads to nonreversible conditions.

A. F. Khokhlov: "On the Use of a Gyroscope-Magnet as a Course Indicator",
Avtomatika i Telemekhanika, Vol 8 (1947), No 4, pp 285-296.

Here the interesting attempt is made to combine the two traditional
methods of course indication, gyroscopic and magnetic. In contrast to the
well-known combinations of this type, wherein the magnetic needle is used
only as a control for the correction moment, there is in this case a fixed
connection between gyroscope and magnet. The magnetic north-south direction
coincides with the rotational axis of the rotor.

For such a device the author sets up a linearized theory for which
at the outset a quite special condition must be satisfied. This condition
combines the gyroscopic moment and the maximum magnetic moment with the
values for the rotational velocity of the earth, the geographical latitude,
and the magnetic inclination. The fulfillment of this condition provides
a simple calculation of the system of differential equations, but it would
require, for practical application, such an enormous gyroscopic moment,
that the oscillating system, because of the magnetic containment, would
have a period of 12 hours at the equator, which would increase to 24 hours
at 60° latitude. In view of the great difficulties involved with the
much shorter Schuler period of 84 minutes, it is obvious that the investigation
here has only theoretical value. There are no suggestions for a practical
application of this gyroscopic device.

One advantage of the fulfillment of the above condition is the fact
that the position of equilibrium of the gyroscope axis is horizontal and
forms the mid point between the meridian and the magnetic north-south
direction, when the condition $\varphi = \mu$ (i.e., geographic latitude = magnetic

When the stated conditions are satisfied, the directional force of the instrument is twice as great as that of a standard gyrocompass; the course errors are therefore only half as large under otherwise similar conditions.

Since the gyroscope of the instrument is supposed to be astatically mounted, it receives its directional force solely from the moment of the magnet connection to it. The instrument considered by the author therefore carries out undamped oscillations around its position of equilibrium. For the damping of these oscillations the same means are employed which have been tested for damping the oscillations of a gyrocompass during adjustment. The author does not go into further detail on this subject. It is to be expected, however, that the extremely high oscillation periods will produce new difficulties in regard to the damping.

B. V. Bulgakov: "The Compounding of Errors in Gyroscopic Apparatus", Ingenieur-Archiv, Vol 11 (1940), pp 461-469.

In the study of errors in the gyroscopes of moving vehicles or aircraft consideration is usually limited to certain typical forms of motion, such as the uniformly accelerated straight-line motion or a circular motion with constant velocity. Even though the results obtained in such cases are sufficient to judge the applicability of a device, there is always the danger that certain combinations of forms of motions will lead to a compounding of errors. In this regard the author attempts to find for a given gyroscope those motions which will produce a maximum error, and to calculate this error. He is successful in doing this for a gyroscopic compass.

The well-known linearized equations of motion for a gyrocompass (Anschuetz-compass) are solved with the aid of operators, whereby the earth's rotation and curvature are taken into consideration. The azimuth deflection, produced in addition to the course-run and accelerations

corresponding time functions of the ship's maneuvers are entered. For the most common case, where the period of a ship's maneuver is small compared to the period of natural oscillation of the compass, the integral can be substituted by a simpler and more easily evaluated expression.

From the discussion of the error formula it is clear that the ship's maneuver which produces the largest theoretical error is an alternate rapid changing of course from north to south and vice versa. The error produced in such a case is the sum of a convergent series. For actual maneuvers, where the change of course would be much slower, much smaller errors are to be expected.

The calculations are considerably simplified when the Schuler 84-minute condition is maintained. The resultant error is then caused solely by the damping of the gyrocompass. As a result of the Schuler condition, the error is equal to zero for an undamped gyroscope.

In a practical example with actual figures, already worked out by Geckeler, the maximum error is computed and found to be in good agreement with the strict value obtained by Geckeler.

A. A. Krasovskiy: "Concerning an Oscillatory Method of Linearizing Certain Nonlinear Systems.", Avtomatika i Telemekhanika, Vol 9, No 1, $pp.\ 20$-29

A theory is developed expressly for the vibration mounting of gyroscopic devices, whereby the author bases his work on the general theorems derived by Bogolyubov, which state that the behavior of certain nonlinear systems in which there are forces of comparatively high frequency can be approximated under certain conditions by the behavior of a linear system whose characteristic curves have been obtained from the original system by a process of interpolation.

The method is illustrated by two examples (simple oscillator with Coulomb friction and a hydraulic servo-motor with a Servo-piston). The

friction force was measured by superimposed oscillations as a function of

the amplitude of these oscillations. Unfortunately, the text does not tell how these experiments were carried out.

B. V. Bulgakov and S. S. Tikhmenev: "Theory of the Sperry Gyroscopic Horizon With Pendulum-Air Blast Correction", News of the Moscow State University, Vol 7 (1937), pp 181-199

The authors present a linearized theory of the Sperry horizon for the following moments:

1) moment of air-blast support,

2) moments of friction around the two Cardan axes,

3) disturbing moments of gravity in the case of such great path deviations that the control pendula are deflected.

The solution of the linearized equations is accordingly carried out in four different zones:

1) very small course changes within which the correction moment is smaller than the friction moment;

2) the range adjacent to 1) up to a complete opening of the control slit by the pendula;

3) the range in which the pendula release the control slits completely, but do not reach maximum deflection;

4) large course deviations after maximum deflection of the pendula.

The solution to range 4) is not carried out, but simply stated qualitatively.

The second part of the article treats disturbing influences such as the changes of indication resulting from the earth's rotation and speed of the aircraft. In the case of the latter, only the longitudinal accelerations are investigated in detail, whereby a table of possible maximum horizon errors is given for the case of constant longitudinal acceleration and a given maximum flight velocity. The case of curved flight is mentioned only briefly.

The numerical evaluation was carried out for an original Sperry instrument.

L. N. Sretenskiy: "The Motion of the Goryachev-Chaplygin Gyroscope." (dedicated to the memory of S. A. Chaplygin), News of the Academy of Sciences of the USSR, Department of Technical Sciences, No 1 (1953), pp 109-119.

Goryachev investigated the motions of a gyroscope whose main moment of inertia satisfied the condition A = B = 4C and whose center of gravity lies in the equatorial plane of the inertia ellipsoid. Chaplygin produced a generalized integration of the Goryachev case with the use of ultra-elliptical integrals. The Goryachev-Chaplygin results are now treated in detail for a specialized case in which a gyroscope has received a large initial moment around a main axis of inertia which passes thru the center of gravity. The motions are then analogous to the so-called pseudo-regular precession in the case of the Lagrange gyroscope.

The expressions in the Chaplygin integrals are developed in series, wherein the higher members can be neglected because of the assumption of a large initial moment. The most important result of the investigations is the fact that the gyroscopic axis, about which the moment takes place, oscillates with a decreasing and then increasing amplitude (vibration). The oscillation frequency is thus proportional, and the vibration frequency inversely proportional, to the initial natural rotation of the gyroscope. The natural rotation itself changes in time with the vibrations.

G. O. Fridlender: "On the Precession of a Gyroscope Under the Effect of an External Moment", Ingenieur-Rundschau, Vol 12 (1952), pp 229-233.

Since investigations on the effect of external moments on a gyroscope generally are limited to the behavior of the gyroscopic axis, i.e., one of the three main axes of inertia, the author investigates the motion of the

instantaneous axis of rotation and the likewise instantaneous axis of momentum. He limits himself to the case of the rapid moving gyroscope which is supported at its center of gravity.

Under the effect of any external moment acting upon the gyroscope, the well-known motions of the gyroscopic axis on a point-, loop-, or wave-cycloid are produced, according to the chosen initial conditions. The author gives for these cases the corresponding motions of the instantaneous vector of rotation and vector of momentum. The drawings given for these cases do not appear to be very reliable, since, for example, one point cycloid is obviously erroneous.

The author mentions the interpretation of Klein and Sommerfeld for the case of the pseudoregular precession, which, similar to the case of Poinsot, describes the motions of the gyroscope by the rolling of a sphere which is fixed in respect to a body on a sphere which is rigid in space.

From these considerations it may be concluded that the moment due to the friction of the air acting on an erratic free gyroscope causes the gyroscopic axis to rise upward, just as the moment of friction of the point on the base.

Ya. N. Roytenberg: "Self Oscillations of Gyroscope Stabilizers",
Prikladnaya Matematika i Mekhanika, Vol 11 (1947), pp 271-280

Here the behavior of a gyroscope stabilizer is investigated, in which a Cardan-suspended gyroscope during precessions around the inner Cardan axes activates a potentiometer which, via an amplifier, turns a stabilizing motor.. The motor provides a moment around the external Cardan axis; this moment imparts to the stabilized system joined with the external Cardan axis a certain insensibility toward external perturbation moments.

The author investigates the case where the potentiometer has a black-white characteristic of the form S sign $/^\beta$, whereby $/^\beta$ is the angle of rotation of the gyroscopic system around the inner Cardan axis. The calculation itself is carried out linearly by area, and the individual solutions then are bunched at the transition point. By entering the condition of periodicity a periodic solution of the system can be found, for which the stability is determined by investigating a system of differential equations.

From an example worked out with actual figures by the author, it is evident that the investigations concerned rather large objects, such as are used in the navy, for from the given data it is evident that the stabilized system has a weight of between $\frac{1}{2}$ ton and 1 ton, and the gyroscope itself might weight about 20 kilograms. The stabilizer motor has a rated current of 6 amperes and produces a stabilized moment of 0.45 kilogram.

I. I. Metalitsyn: "On the Question of Gyroscope Stabilization", Doklady Akademii Nauk SSSR, Vol 86 (1952), No 1, pp 31-34.

In the investigation of stability according to the Hurwitz method, the influence of individual types of forces on the stability cannot be overlooked. The author thus separates his linear system in such a way that the various forces (inertial forces, dissipative forces, gyroscopic forces, conservative forces, and intrinsically nonconservative forces) are entered independently in the stability equation. In this way, he obtains six general rules, which can be of great advantage in the projecting of dynamic systems.

1) When a conservative system is statically unstable, it can not be stabilized by the addition of intrinsically nonconservative forces (without dissipative and gyroscopic).

2) When a conservative system is statically stable, the adding of intrinsically nonconservative forces can make the system unstable.

3) An intrinsically nonconservative system can be stabilized only if gyroscopic and dissipative forces are added simultaneously to the effective forces.

4) A statically unstable system can be stabilized, if dissipative, gyroscopic, and intrinsically nonconservative forces are added simultaneously to the effective forces.

5) If the condition of stability is satisfied, and if the gyroscopic forces are superior to the other forces, the oscillation frequencies of the system separate, that is, the one becomes relatively large, the other relatively small.

6) If the stability condition is satisfied, and the gyroscopic forces are superior, the oscillation with the larger frequency will be more strongly damped than the oscillation with the small frequency.

D. G. Topel'bert: Electronavigational Instruments. State Publishing House for Water Transport, Moscow-Leningrad (1950), 428 pages, 3000 copies, prices 17.60 rubles.

This book, written by a captain in the navy, serves as a text at the advanced training schools of the navy. The greater part of the book (276 pages) is devoted to the gyroscopic instruments used in navigation, chiefly the gyrocompass. The two other sections deal with the Echolot (fathometer) and log.

The introduction to the gyroscope theory in the first chapter is quite extensive, in view of the purpose of the book. The theoretical considerations are based chiefly on "technical" gyroscope equations. The equations of approximation used are those usually employed in the consideration of "small oscillations". They are not derived directly here, but obtained indirectly by means of a linearization of the generalized Euler equations. The mass of the Cardan rings is neglected, and it is assumed that the vector of rotation deviates only slightly from the pronounced main axis of inertia. The precession and the effect of brief disturbances are then investigated on the basis of these simplified equations. For later investigations an expansion of the equations of approximation for rotating systems of reference is necessary.

In the following three chapters (2 to 5) a rather detailed theory of the first approximation is presented for a gyrocompass damped by an eccentrically suspended pendulum and for a gyrocompass with damping tanks. Then the behavior of the gyrocompass on a moving ship is treated, and the theory of the course error and the acceleration error is developed. The condition (Schuler) for an acceleration-free period-adjustment (84-minute principle) is also derived. The question of counteracting the ballistic deviation of the first type leads to the necessity of adjusting the undamped instrument to a natural oscillation period of 84 minutes. The question of counteracting the ballistic deviation of the second type leads to the necessity of either using an undamped instrument, or of cutting off the damping during maneuvering (changes of course and speed).

The quadrantal error of the gyrocompass is also investigated, and methods of correcting it are shown. These observations are, however, more qualitative than quantitative.

Essentially, the theory developed in the book is based on that of the well-known text on gyroscopes by Krylov and Krutkov (1932).

All the values which can be used to judge the operation of a gyrocompass are compiled in a table, and methods are indicated whereby the individual values can be determined by laboratory tests. The degree of accuracy required in these cases is $\pm$ 0.1° for laboratory work and $\pm$ 0.2° to 9.3° for work on an anchored ship.

Chapter 6 presents an elementary theory of the artificial horizon, but only insofar as the horizon is maintanied by means of a gravity moment. This theory suffices for the Fleuriais gyroscopic sextant described in the book.

There is also a brief discussion of a gyroscopic device with which the geographical latitude φ can be measured. The operating principle is based on the fact that the indications of both the gyrocompass and the artificial horizon are functions of the geographical latitude φ. If the exact heading and the exact horizon are known from another source, the geographical latitude can be determined from the difference. It is emphasized, however, that such instruments are not yet sufficiently accurate for use in navigation.

In Chapter 7 the designs of two gyrocompasses are given in great detail. The first one described is a single-gyroscope compass, presumably built in the USSR. Its rotar has a diameter of 25 centimeters and weights about 23 kilograms, and is thus much heavier than the single-gyroscope compasses of ether countries. The gyroscope system is suspended in a very interesting manner by means of wires, and is provided with guide bearings and a vertical control system, which compensates any return moments resulting from the twisting of the suspension wires. Damping tanks of the usual type are used. The course error is eliminated by a special "corrector", which used the speed and geographical latitude as initial data.

The second gyrocompass is the two-gyroscope "spherical compass" of Anschuetz and Company (the firm is not mentioned, however). The three-gyroscope compass is not mentioned.

The following chapters deal with the installation of the gyrocompass an board ship, testing the installed compass, and evaluating the obtained data. The discussions embrace all the instruments connected directly or indirectly with the gyrocompass, such as repeaters, current-supply equipment, course recorders, flight recorders, and autopilots.

Ya. L. Geronimus: <u>Survey of the Works of the Classicists of Russian Mechanics</u>, State Publishing House for Technical and Theoretical Literature, Moscow (1952), 519 pages, 5000 copies, price 22.75 rubles.

This book is a valuable contribution for two reasons. First, it gives a brief but clear survey of many works which would be difficult to compile and review individually; secondly, the work based on the classics in Russian mechanics is followed down to very recent times (about 1950), thus an extensive and valuable bibliography is supplied.

In the chapter on S. V. Kovalevskiy, in addition to a discussion of the "Kovalevskiy case" (a special case of the heavy symmetrical gyroscope), the other classical cases are discussed, in which an integration of the equations of motion for the ordinary gyroscope was possible. There are also brief discussions of the works of Euler-Poinsot, Lagrange, Appelrot, Bobylev-Steklov, Hess, Goryachev-Chaplygin, and of the investigations made by Zhukovskiy with a gyroscope in a liquid. Especially interesting in this case is the analogy between the curvatures of an upright wire with an elliptical cross section subjected to a force and a moment at the free end and the motions of the usual asymmetrical gyroscope.

In the chapter on Steklov the work on the gyroscope turning in a liquid is discussed, and a corresponding survey of later works on this theme is given. These purely analytical-mechanical investigations have not been continued in recent times; nor are there any known practical applications of this theory.

The chapter on Krylov gives only a brief description of the work which is presented in great detail in the book by Krylov and Krutkov.

<u>Ya. V. Linnik and V. S. Novoselov:</u> "Random Disturbances of the Regular Precession of a Gyroscope", <u>Prikladnaya Matematika i Mekhanika</u>, Vol 18 (1953), pp 361-368.

Over half of this article is devoted to purely mathematical investigations on the probability distribution of the solutions of a system of differential equations. These investigations are finally applied to the case of the regular precession of a symmetrical gyroscope, whose moments of inertia and gravity are subject to certain random changes. A Gauss distribution is assumed for these changes.

Formulas are given with which the density of probability for the deviations of the gyroscope motions from the regular precession can be computed from the corresponding matrices of correlation.

<u>V. V. Golubev:</u> <u>Lectures on the Integration of the Equations of Motion for the Rotation of a Rigid Body Around a Fixed Point,</u> State Publishing House for Technical and Theoretical Literature, Moscow (1953), 287 pages, 8000 copies, price 6.15 rubles.

This book represents an expansion of lectures delivered at the University of Moscow. It is called by the author a continuation of the book on the analytical theory of differential equations (published in 1950) and concerns the application of the methods of the theory of analytical functions and the analytical theory of differential equations to the classic problem of the rotation of a rigid body around a fixed point. The author states that his special task is the application of modern analytical methods to practical cases. In this connection he quotes Chekhov, who once said, "If a pistol is drawn in the first act of a play, it should be fired by at least the third act." The author draws up some heavy artillery, such as the theory of elliptical, hyperelliptical, and ultraelliptical functions, Abel integrals, and Riemannian spaces, and lets go with a loud noise. The book deals much more with mathematics than with physics; at many places mathematical problems are treated which have nothing at all to do with the gyroscope. In many instances it is evident that the author's preference for mathematical analysis does not necessarily represent the shortest path toward a solution of the problem at hand.

To a certain degree the book is a tribute to S. V. Kovalevskiy, since references to the work of Kovalevskiy both in the introductory historical survey and in the text itself are inordinately frequent.

In the final chapter the author even cites and discusses portions of correspondence with Kovalevskiy. The basic idea, with which Kovalevskiy obtained the classical results, is developed in detail by the author and presented in the light of modern analytical methods. This idea is that in the solutions of the equations of motion the time can be considered a complex value, and thus the theory of functions can be drawn upon for the solution of the problem.

In comparison with the detailed treatment of the Kovalevskiy case, the well-known other cases, in which the basic equations of the gyroscope can be integrated, are treated only briefly. These cases are:

1) Euler - Poinsot

2) Lagrange - Poisson

3) Hess - Appelrot

4) Goryachev - Chaplygin

5) Bobylev - Steklov.

In all these cases special assumptions are made concerning the form of the inertia ellipsoid or the position of the center of gravity, or both, to the extent that a fourth integral can be added to the well-known three integrals of the equations of motion, and the solution traced back to a quadrature. Under such conditions, elliptical integrals appear again and again, and the reversal of them leads to the solutions. More than 50 pages of the book are devoted to these reversals of elliptical integrals.

On the whole, the book can be considered a presentation of the classical integrable cases for the motion of a gyroscope in the light of modern methods of mathematics.

V. A. Pavlov: <u>Principles of Design of Gyroscopic Instruments</u>, State Publishing House for the Defense Industry, Moscow (1946), 6000 copies, 223 pages, 16 rubles

This textbook of the Institute of the Aircraft Industry is intended for designers who are concerned with the development of gyroscopic devices. The author, therefore, presents a compilation and summary of the many methods which have been developed for the design of small and light gyroscopic devices, in order to save many designers the trouble of solving

After a short historical introduction, the first five chapters deal with a broad but not always clear introduction to the general gyroscope theory. For instance, on pages 33 to 35 there is a superfluous and much too involved derivation of the general theorem of the conservation of areas. The theory is developed to such an extent that the equations of approximation, which apply for small deviations in the gyroscopic axis and which are sufficient generally for the calculation of gyroscopic phenomena and gyroscopic instruments, are derived. No special theory for gyroscopic instruments is given, but in the later chapters there is an explanation of the methods by which certain individual parts of gyroscopic instruments can be calculated.

Chapter 6 presents a general survey of the various uses of the gyroscope, without going into great detail. Only foreign designs are discussed. The gyrocompass, the first gyroscopic device to be put to practical use, is mentioned only briefly, since the book is written not for the navy but for the air force. The most varied designs of directional gyros are discussed in great detail. Along with the discussions of such types as Anschuetz, Obry, Sperry and Brown, there are also descriptions and partial data given on instruments made by Ach, Hartmann and Braun, and the gyroscopic control instrument for guns made by Krupp. The basic behavior of these instruments, especially the deflection caused by the earth's rotation, is discussed. The single-track-railroad gyroscope of Shilovskiy is the only gyroscopic stabilizer mentioned. Of special interest are the descriptions of two test gyroscopes, both referred to as "accelerographs", but which do not actually measure accelerations. The one is a free gyroscope with three degrees of freedom, which is used to record the angle of rotation; the other is simply a turn indicator (gyroscope with two degrees of freedom and spring mount), with which the turning speed can be measured.

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The following chapter deals with the subject of methods of powering the gyroscope, and the advantages and disadvantages of the various methods (pneumatic drive with Venturi tube or pump, electric drive with direct or alternating current) are compared. The author comes to the conclusion that the use of three-phase alternating current is best, because of greater accuracy, constant speed, more rapid attainment of full speed, and the fact that no heating is necessary.

Special importance is then ascribed to the "choice of the principal scheme" of the gyroscopic devices. Using a directional gyro with a rated accuracy as an example, the author shows how data on the physical properties of the rotor and ball bearings can be applied to obtain a minimum value for the momentum, at which the required accuracy ban be maintained. An attempt is made to summarize the various designs of the past decades as a basis for predicting the trends and needs for the future. Only foreign designs are again mentioned here in respect to actual practical examples.

The remaining chapters are devoted to the individual parts of gyroscopic instruments. In the discussion of the rotors the influence of air- and bearing friction is considered, and a detailed analysis of the various cross-section forms and dimensions is worked out. Although the designs mentioned here are again exclusively foreign, there are figures given in various tables and charts for unidentified gyroscopes, which may possibly be of Russian design. Two of these gyroscopes are small and relatively light (714 and 788 grams), whereas the other three are 124 and 136 millimeters in diameter and weight from 2.9 to 3.3 kilograms. The problem of material for the rotor and the calculation of the strength and critical speed of the rotor shaft are investigated.

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The ninth chapter, the largest in the book, deals with the problem
of bearings for the rotor and the Cardan rings. Detailed calculations
of ball bearings and pivot bearings are given, and data is compiled on
the friction, tolerances (axial and radial) and strength of all types of
ball bearings. A table for Russian ball bearings is also given. The
problem of bearing size, which is difficult because of the lack of
knowledge of the expected stresses of the individual axes, is facilitated
by the compilation of emperical data (table on page 137).

In the discussion of the Cardan suspension attention is paid chiefly
to the problem of reducing the friction by means of pivot bearings. A
great number of designs are discussed, most of which are foreign. The
effects of bearing friction and tolerances, which are extremely important
in a Cardan suspension, are treated in the text and in diagrams and tables.

Chapter 10 contains a discussion of the most varied types of correction
devices which are necessary either for compensating the effect of the
Earth's rotation on the gyroscope or for maintaining a given direction
with the aid of a magnetic needle or a pendulum. The difference between
the indicators which determine the deviations from the desired position
and the members which provide the correction moments is emphasized.
The various types of correction-moment producers and their advantages
and disadvantages are discussed, and their characteristic curves are
presented in diagrams.

The last two chapters treat the power supply equipment and the
controlling gear. This is a very well organized compilation of otherwise
widely scattered information on the friction of sliding-, brush-, and
roller contacts and the contact resistances of the various types of power
supply. Presumably the data represents the results of Russian investigations,
most of which were carried out on foreign equipment.

In the discussions of controlling gear one unidentified design stands out as especially primitive and is possibly a Soviet model. All the other items of controlling gear mentioned are the well-known instruments of Sperry, Siemens, Anschuetz, and Obry. The calculation of the stresses which controlling gear must assume is also important.

The book presents a systemmatic compilation of data which is of great value to the designer. Even though the desgriptions of Soviet instruments or parts of instruments are infrequent, they do point to the basic trends in Soviet gyroscope development.

Handbook for the Designer of Precision Instruments (Spravochnik Konstruktora Tochnykh Priborov), I. Ya. Levin, Editor, State Publishing House for the Defense Industry, Moscow (1953), 616 pages, price 23 rubles.

This extensive handbook contains a great deal of important details for the designing of gyroscopic devices. Especially important are the nearly 100 pages of data on the various types of Soviet ball bearings, which include not only the usual norms but complete imformation on the friction and tolerances of special bearings of the type used in gyroscopic instruments.

A. I. Nekrasov: A Course in Theoretical Mechanics, State Publishing House for Technical and Theoretical Literature, Moscow-Leningrad (1945-1946), 2 volumes, 355 pages and 456 pages, price 9.50 rubles and 14.50 - rubles.

Only a very small part of this textbook for the higher technical schools and universities contains information on the gyroscope theory. Kinematics is treated only briefly in the first volume. The second volume presents a somewhat more detailed presentation of the concepts of moment of inertia, inertia ellipsoid, energy-, and momentum ellipsoid, but the actual gyroscope dynamics is limited to a brief treatment of the Euler case of the force-free asymmetrical gyroscope and the Lagrange case of the heavy symmetrical gyroscope. In the first instance, the procedure is exclusively that of Poinsot without the use of elliptical functions. In the second case, the solution is indicated, but not carried out.

There is a brief account of the various uses of the gyroscope.

V. N. Okunev: <u>The Free Motion of the Gyroscope</u>, State Publishing House for Technical and Theoretical Literature, Moscow-Leningrad (1951), 379 pages, price 14 rubles.

The book deals with the motions of a gyroscope with three degrees of freedom rotating around a fixed point in a coordinate system. The investigations are carried out in an analytical form and in keeping with the classical gyroscope theory. The Euler angles are used for the most part to describe the motions of the gyroscope, but the designation "swing angles" is also used, which offers certain advantages in the investigation of small oscillations of the gyroscope.

The book treats only a part of the classical gyroscope theory, however, but the material presented is fully treated. In his endeavor to provide a full treatment, the author frequently includes material which is obviously not relevant. The expansiveness of the book is due in part to the fact that the author presents each formula in its most explicit form and frequently repeats a formula given earlier in the text instead

of merely referring to it. There are places in the text where groups of formulas are given, which are quite imposing, but not necessarily distinct. The presentation itself, however, is generally quite clear and understandable.

In the first part of the book both the well-known connections between the Euler angles and those of the "swing angles" and their connections with the Euler angles are to ge found. The fact that the so-called "regular precession" is defined kinematically only and treated fully in the introductory chapter is unusual. Epicycloidal, pericycloidal, hypocycloidal, and anticycloidal motions are investigated.

In the discussion of the asymmetrical gyroscope the author avoids a presentation of the Poinsot motions and gives only the usual integration of the Euler equations with the aid of the Jacobi elliptical functions. The solutions are then simplified for certain special forms of the inertia ellipsoid and discussed.

The greater part of the books deals with heavy symmetrical gyroscopes. The free gyroscope (center of gravity above the support point) and the pendulous gyroscope (center of gravity below the support point) are treated separately. The influence of friction on the motions of the gyroscope is treated in particular detail, whereby three different cases are distinguished:

1) The friction moment is perpendicular to the gyroscope axis and proportional to rotation speeds of the gyroscope axis;

2) The friction moment is in the direction of the gyroscope axis and is proportional to the intrinsic rotation velocity of the gyroscope axis;

3) The vector of the friction moment has both an equatorial and axial components.

Unfortunately, these extensive investigations cannot be applied directly to the conditions for a Cardan suspended gyroscope, since the "swing angles" used are not identical with the angles at the Cardan Suspension. As indicated in the preface, the author is more concerned with the application of his theory to the motions of free-flying rotating missiles. All these investigations in which the friction is taken into account are simplified to the extent that only small deviations of the gyroscope axis from known motions are assumed.

The last part of the book contains a series of results and diagrams of trajectory curves which are not to be found in other books.

L. G. Loytsyanskiy and A. I. Lur'ye: A Course in Theoretical Mechanics, State Publishing House for Technical and Theorltcal Literature, Moscow-Leningrad (1948), 2 volumes, 399 pages and 580 pages, price 13 rubles and 18 rubles.

This extraordinarily extensive textbook on theoretical mechanics, which is widely used in the Soviet Union, contains a seventy-page treatment of the gyroscope theory which includes some applications of the gyroscope in practical use.

In the first volume of the work kinematics is treated in the usual manner, except that there is an unusual amount of vectorial presentation, which provides in many places a degree of clarity to otherwise cumbersome formulas. Here too, the most general case of the motion of a rigid body (combination of rotation and translation) is investigated.

After introductory discussions of centrifugal- and inertia moments and energy and momentum on rotating rigid bodies the second volume presents a theory of approximation for gyroscope phenomena, with the aid of which certain technical applications (Obry's gear, nautical gyrocompasses by Schlick and Sperry, single-track railroad of Scherl, Shilovskiy and

Brennan) are investigated. This theory is limited to the symmetrical gyroscope. For the asymmetrical gyroscope only the well-known Euler equations are derived, but not integrated.

The case of the heavy symmetrical gyroscope is considered for "small oscillations", and this theory is applied to the motions of rotating missiles.

Much interesting and important material is to be found here on the gyrocompass, gyroscope single-track railroad, and the investigation of the edge-runner mill.

S. A. Ginsburg, I. Ya. Lektman, and V. S. Malov: The Principles of Automatics and Telemechanics, State Publishing House for Power Engineering Literature, Moscow-Leningrad (1953), 432 pages, price 9.75 rubles.

This is a textbook for engineers and technicians in the field of automatics. It contains descriptions and elementary calculations of the predominantly electrical components which are found in servo mechanisms. Since many of these components are used in gyroscope instruments, these descirptions have a certain importance. Some of the subjects treated are:

> Potentiometers
>
> inductive oscillators
>
> capacitive oscillators
>
> piezoelectric oscillators
>
> relays
>
> electromagnetic couplings
>
> miniature motors
>
> torque-producing elements
>
> machine amplifiers (amplidyne)

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magnetic amplifiers

tube amplifiers

photoelectric amplifiers

selsyns

magnesyns

bolometers

self balancing bridges

Data is not given for all these components, and it is not evident from the description whether the products are of Soviet or foreign manufacture.

A. M. Bogdanov-Cherrin: Mechanics in Aeronautical Engineering, State Publishing House for the Defense Industry, Moscow (1952), 443 pages, price 11.65 rubles.

This is a textbook for aeronautical engineers, technicians and mechanics. It presents an elementary introduction to mechanics by means of examples from the field of aeronautical engineering. Since the book is intended for students with only a Soviet intermediate school education, no differential calculus is included.

The astonishing thing about this book is the fact that the gyroscope, which has such a wide application in aeronautical engineering, is not mentioned at all, with the exception of a completely elementary example of kinematics. This fact is all the more astonishing since the gyroscope laws and some simple applications of the gyroscope are treated in the Soviet intermediate schools.

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G. K. Suslov: Theoretical Mechanics, State Publishing House for Technical and Theoretical Literature, Moscow-Leningrad (1946), 655 pages, price 25 rubles.

This textbook on theoretical mechanics contains an astonishingly detailed (117 pages) account of the general gyroscope theory. Much of the material presented here is to be found only in the handbooks. The description is limited to purely theoretical considerations, and no attention is paid to practical applications.

In the introductory chapters the equations of motion of a rigid body are derived in the most generally valid form (6 degrees of freedom, various types of coordinate systems and various necessary conditions). These equations are then simplified for the well-known classical special cases and integrated.

These cases are:

1) the Euler gyroscope (i.e., the foree-free Poinsot and McCullagh motion);

2) the Lagrange gyroscope (a heavy symmetrical gyroscope, whose center of gravity lies on one of the main axes of inertia);

3) the spherical gyroscope (i.e., a gyroscope whose three main moments of inertia are all equal);

4) the Kovalevskiy-gyroscope (i.e., a symmetrical gyroscope with quite special inertia ellipsoid and with the center of gravity in the plane of symmetry);

5) the Hess gyroscope (an asymmetrical gyroscope with quite special location of the center of gravity and special initial momentum);

6) the Bobylev-Steklov gyroscope (in which the moment of inertia around the main axis, on which the center of gravity lies, is twice as great as one of the two other moments of inertia).

In the treatment of all of these cases well-known principles or

effects are often given little known designations — a phenomenon which

is extraordinarily frequent in Soviet literature.

Non-holonomic systems are also treated. For example, a general

formulation of the d'Albert principle for this case is given, and a very

general case of the sphere rolling on a space is treated, whereby a

coordinate system rotating with the curvatures of this space is used.

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BOOK REVIEWS

German manuscript

Ye. L. Nikolai: Giroskop i nekotoryye yego tekhnicheskiye
primeneniya [The Gyroscope and Some of Its Technical
Applications], with comprehensive introduction, State
Publishing House for Technical-Theoretical Literature,
Moscow-Leningrad, 1947, 152 pages, first edition,
15,000 copies, price 2.25 rubles.

This small book is one of a popular scientific-technical
series which are published in the Soviet Union in large numbers
and in many editions. It contains an elementary theory of simple
gyroscopic phenomena as well as of a series of gyroscopic devices.
According to the author's preface, the book directs itself primarily
to such technicians and mechanics who do not possess special mathe-
matical or physical training, but who deal with gyroscopic devices.
For readers with some higher training, considerations are inter-
spersed in notes at various points of the text, which however are
also fully elementary in scope. The attempt to explain the simplest
gyroscopic phenomena (precession and gyroscope moment of a directed
gyroscope) without use of the impuse law and without explaining the
vector concept leads partly to quite tedious and by no means clear
explanations.

In the discussion of the gyroscope, in addition to the generally
known devices (Obry's torpedo, Howell's torpedo, gyroscopic course
indicator, turn-and-bank indicator, monorail, gyrocompass, and arti-
ficial horizon), a device is mentioned which is designed for use in
airplanes, and with whose aid pitch and yaw may be determined. It

simply involves a built-in horizon displaced by 90 degrees and
possesses a somewhat different indicating installation. Particu-
lars as to whether this device is being built in the Soviet Union
are lacking. In the discussion of the monorail one learns that dur-
ing the twenties the construction of an experimental line between
Leningrad and Gatschin was planned. This project, however, was
never carried out since the preliminary experiments were unsatis-
factory.

The gyrocompass, to which the author devotes an entire
chapter, is explained very thoroughly and broadly in the Sperry
design form. The mode of operation of the two damping methods
(eccentrically guided pendulum and antirolling tank with mercury)
is explained in detail. It is rather surprising that during the
otherwise quite detailed discussion of the various errors (course
error and acceleration error) the rolling error is not mentioned at
all, and nothing is said about the triple gyrocompass.

Ye. L. Nikolai: Teoriya giroskopov [The Theory of Gyroscopes].
State Publishing House for Technical-Theoretical
Literature, Moscow-Leningrad 1948, 171 pages, First
edition, 10,000 copies, Price 6 rubles.

The book provides a short, more or less elementary theory
of gyroscopic phenomena with consideration given to various applica-
tions of the gyroscope. It presents a revised and extended version
of gyroscopic theory found in the author's textbook on theoretical
mechanics. The presentation is very broad and detailed, yet quite
comprehensible as is frequently encountered in Russian textbooks.

The following are noteworthy in the treatment of the gyroscopic

theory.

1. The use of generalized Euler equations (Section 8), i.e. of gyroscopic equations which are written in an arbitrary reference system not fixed with respect to a body. Their use provides advantages in the treatment of many applications of the gyroscope.

2. The use of a complex calculating method (Sections 28 and 35) for the theory of the symmetric gyroscope, which, although not new, is not commonly used.

3. A theory of the gyroscope mounted on gimbals (Chapter VI) in which the mass of the gimbal rings is considered. The equations are derived, however, no solutions are investigated.

A rather detailed description and theory of the various gyrocompass designs is presented in the treatment concerning the applications of the gyroscope, in addition to a series of smaller examples (grinding pressure of edge-runner mills, suspension reactions of unbalanced rotors, gyroscopic forces of rotating machine components on vehicles). The problem of damping is examined in greater detail and an elementary derivation of the course and acceleration error is also presented. The Schuler 84-minute principle is briefly mentioned in this connection, however without indication of closer details. The last chapter treats the question of the critical rates of revolution of elastic waves taking into account gyroscopic effects.

V. M. Shlyandin: Elementy avtomatiki i telemekhaniki
[Elements of Automation and Servomechanics], State
Publishing House of the Defense Industry, Moscow, 1952,
435 pages, Price 11.85 rubles.

This textbook, written for the training of aircraft-instrument engineers, contains a series of subjects which are also

significant to gyroscope technology. Chapter II contains a detailed survey of the various types of pick-ups including the methods used for calculation (for example, resistance transmitter, inductive, capacitive, and photoelectric pick-ups). Special problems, as for example the construction of transmitters with specified character-istics (sine- or cosine-characteristic) are also treated.

A gyro-induction compass is described in Section X,2. According to the author's information the latest (1952) designs of the induction-compass are included. These consist of a system of three inductive transmitters, each displaced by 60 degrees of the other and each respond to the earth's magnetic field. The only function of the gyroscope is to maintain the three transmitter elements in a horizontal plane. It is loosely stated that the gyroscope is used as a yaw and roll gyroscope without indicating principles or constructive details. By use of the gyroscope, pivoting of the transmitter elements around the horizontal axes is avoided and thus the northerly turning error is almost eliminated. The gyro-induction compass possesses a guaranteed accuracy of ± 2 degrees.

As described in Section X,3 this compass is also used as measurement transmitter of an automatic pilot. By means of this device the path of an airplane may be determined by integration of the pertinent values of course, speed, and wind-force and direction. The pertinent location is directly indicated by means of two hands on the map.

Ye. V. Ol'man, Ya. I. Solov'yev, V. P. Tokarev: Avtopiloty [Automatic Pilots], State Publishing House for the Defense Industry, Chief-Editor for Aeronautics Litera-ture, Moscow, 1946, 472 pages, First Edition, 6,000 copies, Price 30 rubles.

This book contains a description of automatic pilots of all essential systems, foreign as well as Soviet. In addition to a presentation of the historical development of automatic pilots, the fundamentals of a theory of automatic control of airplanes is treated.

According to the author's preface the book is intended for engineers, designers, and developers of automatic pilots and is to serve simultaneously as a textbook for students in these fields.

The book treats an extraordinarily extensive subject field, with instrument technology, undoubtedly, constituting the main theme. In contrast, the occasionally interspersed theoretical considerations, as for example in Chapter II, are hardly significant. The book is essentially of a descriptive nature and enters into details in places. The intensity of the descriptions of the individual designs frequently permits inferences as to how much attention has been paid to the instruments(at least within the author's field) and what significance is attributed to them.

By far the greatest part of the book is devoted to the description of the various designs. After presenting a rather consistent historical survey in Chapter III of the predecessors of today's automatic pilots, the next two chapters are devoted to the description of foreign designs. Finally, Chapter VI contains quite an extensive description of Soviet automatic pilots which were developed during the years 1932 to 1942. In connection with this it is mentioned that "one of the first automatic pilots made in the Soviet Union" is the type ABP-10. This automatic pilot which appeared in 1934 differs from its predecessors ABP-1 and ABP-3 only in details, which, although necessary for safe operation especially at low temperatures, are of no significance to the principle of the instrument. Three-position gyroscopes are still used for this purpose,

which are pneumatically driven and supported and which are differentiated exclusively by the nature of their support.

The developed automatic pilot of the type STL-4 which "was constructed by the designers Selizki, Timofeyev, and Lusis," essentially corresponds to the well-known Sperry-pilot of 1934. The Sperry gyrocompass in conjunction with the Askania telecompass is used as course compass. The Sperry horizon is used for stabilizing the longitudinal and transverse position. Since this design has evidently not proven itself, the Sperry automatic pilot was copied without any change as type ABP-12 and after a specific test period was changed in some details so that the type ABP-12-D was created. These changes concerned measures to extend the temperature range up to -50°C as well as increasing the peak performance of these pneumatic devices. The device evidently must have been used extensively in this form, for the description treats very comprehensively all details of installation, ground, and flight testing.

Chapter VII is devoted to a further development of the automatic pilot ABP-12-D the type AP-42, which stems from the designers Semenov and Ol'man (author of the book). Nothing was changed in the method of control, but a series of construction changes was instituted. Thus in the case of the gyroscopes the arrest of the hitherto copied Sperry gyrocompass was changed. The horizon was evidently accepted without change. At the time the book was drafted this automatic pilot evidently represented the most modern Soviet device of this kind. For this reason very comprehensive descriptions including installation drawings, test instructions, and operating directions, even instructions for eliminating errors, are presented.

Chapter VIII treats the uniaxial directional controls in use

at that time. Conspicuous here is the very intensive concern with
the automatic pilots of Askania and Siemens. This explicitness
coupled with a critique of the devices permits the conclusion that
these types were extensively tested in Soviet Russia, and that they
possibly were used as original designs for their own developments.
The Soviet automatic pilot control of type AK-1 described in this
chapter (a design by engineer Sorokin) is nothing more than the
directional control portion from the triaxial control ABP-12, thus
from the Sperry control. In this connection it is reported that
at the beginning of the war all Soviet passenger airplanes of the
type PS-84 were equipped with automatic pilot controls.

In the last chapter of the book, descriptions of the modern
American automatic pilots "Sperry A-5." and "Minneapolis - Honeywell
C-1" are presented. Tests of these devices at the time the book
was drafted had evidently not yet been made, since the authors limit
themselves to a relatively short description.

Of interest is the fact that at the end of the book in the
tabular survey of the various automatic pilots with their most
important characteristics, foreign designs are exclusively used
despite the fact that in the book itself Soviet devices are de-
scribed in detail.

Seen from the standpoint of gyroscope technology, Chapter I
possesses another specific significance since in this section gyro-
scopic devices in general and their individual components are dis-
cussed. Here Soviet designs are also briefly described.

GERMAN REVIEW OF RUSSIAN WORKS ON GYROSCOPES

B. V. Bulgakov and Ya. N. Roitenberg, "Concerning the Theory
of Power-Assisted Artificial Horizons," Izvestiya Akademii
nauk SSSR [News of the Academy of Sciences USSR], Depart-
ment of Technical Sciences, Vol 3, 1948, Pages 289-292.

This work, which consists of only four pages, is particularly
noteworthy because it shows the manner in which the apparatus which
was treated in detail by Roitenberg in an earlier publication _____ has
subsequently been developed and modified. While the original design
by Roitenberg in 1946, which provided a Cardan suspended platform
on which there were four gyroscopes, was a type in which the system
lost a certain directive force by placing the center of gravity lower
than the point of intersection, they now have switched over to making
the platform systems astatic with the gyroscopes and for this reason
having the (power) assistance actuated by small gyro pendulums which
are attached to the gyro housing.

This development indicates a distinct parallel to the develop-
ment of the artificial horizon itself. While the Anschuetz (Dr.
Hermann Anschuetz-Kaempfe) artificial horizon still operated with a
lower center of gravity location, the later Sperry horizon was
astatically located and actuated the (power) assistance by small
pendulums.

It is worthwhile to note that this parallelism was not discovered
by the authors until quite late. Apparently, they at first thought
only of dealing with a replacement, which seemed practicable for the
apparatus, of the moment of gravitational force by pendulous controlled

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moments without changing any of the principal methods of operation
of the mechanism. Only now in this publication is there a reference
to the closely related possibility of transposing the assignment of
the gyro pendulum to the assisting motor, exactly as has long been
the case with the Sperry horizon. The findings of this work consist
in the indication that one can synchronize such a system (likewise
a Schuler type) to a natural frequency period of 84.4 minutes and
that then, except for a course error, no acceleration error (ballistic
deviations) will appear.

At the conclusion of their studies the authors indicate that
it would be most practicable to unite both methods of assistance
with one another so as to attain a damping of the timing oscillations.
In this case, therefore, each of the two controlling pendulums would
have to be connected to each of the two assistance motors and the
polarity of the assistance moments selected accordingly.

> Ye. L. Nikolai, Giroskop v kardanovom podvese [The
> Gyroscope in Cardanic Suspension], State Publishing
> House for Technical-Theoretical Writing, Moscow, 1944.

The monograph, of 83 pages, essentially contains the results
of two earlier publications of the same author.
The influence of various
kinds of friction on the movement possibilities of a Cardanic suspended
gyroscope is exclusively studied. Of course, the characteristic sizes
of the gimbal rings are not neglected as is usually the case; however,
since the author simplifies his equation of motion by linearization,
he misses the interesting and, for the technical application of
Cardanic suspended gyrocompass, the extraordinarily important effect
of the azimuthal variations of the gyro axis under the influence of

the nutation oscillations. If for this reason the monograph must be regarded as obsolete, several partial results still claim considerable interest.

In the first section the equations of motion for a Cardanic suspended gyroscope are arranged in a perfectly common form -- but then, for the case of the "quick gyroscope," they are simplified by the elimination of all nonlinear units. The linear equations thus obtained are then integrated one after another for the following cases:

1. Cardanic suspension without friction and damping but for various sloped positions (because of the nonlinear units not being used in this case, the results are completely invalid).

2. Damping moments proportional to the rate of revolution around the gyro axis.

3. Impedance of one of the gimbal rings -- thereby a loss of the stabilizing properties.

4. Constant external moment, no damping; pseudo-regular precession.

5. Constant external moment with damping proportional to the speed.

6. Simplified calculations of the precession by elimination of the inertia units.

7. Action of the gyroscope in the presence of coulomb friction around the gyro axis.

8. The same case (7) simplified by elimination of the inertia units.

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Of the problems listed above, the seventh problem takes up by far the greatest part of the monograph. The author solves this nonlinear problem by the piecemeal joining together of the linear partial solutions by frequency. For this purpose he uses a graph plane which contains the speeds around both gyro axes as the axes of the coordinates. Moreover, he distorts the scale so that the track curves become circles in the single quadrants of this plane and can therefore be easily drawn. From time to time the central points of this arc of the circle jump from one quadrant to another while in transition. With this lengthy explanation of the "method of the image point," several special cases are then discussed in which the total nutational action takes place in one quadrant of the image plane and in which the speeds therefore retain their signs. Such is possible if there are strong external moments and the nutation impulses remain small. In spite of the presence of friction, undamped oscillations can appear in special cases. Moreover, special cases are also possible in which the movement, while transiting, comes to rest in one of the two coordinates.

For the case in which the friction moments remain small as compared to the gyroscope moments, approximate formulas are easily derived. In the case of coulomb friction there also exists a sort of pseudo-regular precession. The nutation amplitudes, however, decline (during the precession) to a certain boundary value for which one of the previously studied stationary movements then adjusts itself with change points. Besides deriving practicably useful approximate formulas for this case, the author still shows that from a measured track curve of the gyroscope apex, the coulomb frictions present in the Cardan suspension can also be determined conversely.

Ya. N. Roitenberg, "The Multiple Gyroscope-Horizon," Priklad-
naya matematika i mekhanika [Applied Mathematics and
Mechanics], Vol 10, 1946, Pages 101-124.

In his very detailed and valuable work Roitenberg seizes upon
the idea which A. N. Krylov had discussed in his book on the "General
Gyroscope Theory and its Technical Application." Krylov had suggested
for the stabilization of ships, a platform on which two gyroscopes,
one each for rolling and yawing, were to be fastened. Instead of
the one gyroscope for each axis suggested by Krylov, Roitenberg now
takes two gyroscopes and investigates the operation of a system
composed of four gyroscopes during various motional conditions of
the ship on which the mechanism was to be located.

A valuable finding of this work is shown by the fact that the
errors of the 4-gyroscope mechanism can, in part, be considerably
smaller than those of a single-gyroscope mechanism with similar data.

The 4-gyroscope mechanism is described in the first section.
It consists of a Cardan suspended frame on which the four gyroscopes
are so fastened that their housing can rotate around an axis passing
vertically to the platform. The rotor axes of each two of these
gyroscopes are aligned in the normal position parallel to one another.
Their movements around the vertical axis of plane, however, are not
independent of one another, but rather are coupled together by rods.
The gyroscopes with parallel-lying rotor axes can therefore only
turn in an equal, but oppositely located angle around their vertical
axis of plane. These rotary motions around the vertical axis of
plane are still influenced by spring clamps which continually seek
to draw the gyroscopes back to a normal position. The system has a
(power) assistance apparatus around the two gyro axes of the platform;

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the center of gravity lies under the point of intersection of the two Cardan axes.

In the theory of the mechanism, frictions around the gyro and gyroscope housing axes are eliminated. Moreover, the acceleration units are cancelled out in the manner which is usually approved for technical gyroscope problems and therefore are computed with the "technical gyroscope equations." The rotation and curvature of the earth, however, are included since they are important for further theory.

After dealing with the movement units, the action of the mechanism on an immobile base (laboratory) is then computed. As expected, one gets a timing oscillation and an earth rotation error besides. Since the latter is composed of known quantities, it can be determined by calculation and can therefore be compensated for.

In the calculation of the important rolling error for ships, it is assumed that the mechanism moves on an orbital circle in a vertical plane. For this case one gets a recording error which is significantly smaller for the described 4-gyroscope horizon than the error of a similarly constructed mechanism with only one gyroscope. The error of the single-gyroscope pendulum is proportional to the relationship of the wave frequency to the characteristic gyroscope frequency -- therefore a very small quantity; the error of the 4-gyroscope mechanism on the other hand is proportional to the square of this relationship.

The errors of 4-gyroscope and single-gyroscope mechanisms may also be compared with one another for cases of linear and curve accelerations.

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Since a characteristic oscillation period of 84.4 minutes for the single gyroscope horizon had proven especially favorable (Schuler's 84 minute principle!), the author also investigates his 4-gyroscope mechanism with the same modulation. In so doing he comes to the not too astonishing conclusion that when the (power) assistance is switched off, the mechanism does not show a course or acceleration error. Moreover, he can show that the oscillator impulse vector of all four gyroscopes is proportional to the absolute speed of the ship. Each pair of gyroscopes indicates for itself a component of this absolute speed.

Especially important for gyroscope mechanisms is the question of the accumulation of error in a series of different maneuvers, which was first studied by B. V. Bulgakov. Roitenberg studies this question for an 84-minute system. With the aid of the method previously applied by Bulgakov, he succeeds in figuring out the maximum error of his mechanism in the form of a series from error integrals. For a practical example of this, he comes to the conclusion that the maximum possible error of his mechanism during the unfavorable series of different ship maneuvers is exactly half as great as the corresponding error of a single gyroscope mechanism.

The weaker the (power) assistance is around the gyro axes, the smaller is the ballistic error in the maneuvers of short duration.

At the conclusion of his studies Roitenberg again discusses the case of a 4-gyroscope mechanism with a characteristic oscillation period which is considerably smaller than 84.4 minutes. This question is of great practical significance since an oscillation period of 84.4 minutes can only be reached with difficulty. In doing this he comes to the conclusion that in the case of a characteristic oscillation

period which is negligible in comparison with 84.4 minutes, the
ballistic recording errors of the 4-gyroscope mechanism are smaller
by the factor 1/e than those of a single gyroscope mechanism.

> D. A. Braslavskiy, S. S. Logunov, and D. S. Pal'por, Raschet
> i konstruktsiya aviatsionnykh priborov [Design and
> Construction of Aeronautical Equipment], State Publishing
> House for the Defense Industry, Moscow, 1954. 583 Pages,
> price 19.20 rubles.

This extensive book should be used as a text for schools which
are concerned with the development of aeronautical equipment designers.
It apparently originated in collaboration with the Mosco Ordzhonikidze-
Technicum for Aeronautical Equipment Designers.

The work, which is divided in three parts, discusses first of
all, in about 170 pages, general questions of aeronautical equipment
design; the second part of the book, almost 250 pages, contains
descriptions and designs for the most important aeronautical equip-
ment -- without gyroscope equipment -- while the third part consisting
of 150 pages is concerned with gyroscope equipment and automatic
pilots.

The introduction of three chapters is a model example for
primarily historical introductions as have been customary in the
Soviet Union for several years. The reader is spared hardly a single
name of all of the many original discoverers in Russia and with an
enviable carelessness practically all areas which are connected with
aeronautics or its equipment are described as discovered and machined
by the Russians. Two sentences, which are supposed to characterize
the situation in the gyroscope field, may serve as a typical example:

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"In the year 1765, L. Euler, a member of the Russian Academy of Sciences, in his famous dissertation on the theory of the movement of a rigid body, gave a schematic representation concerning the question of the movement of a rigid body around a fixed point. The leadership in general and applied gyroscope theory was later taken over by the Russian scientists A. N. Krylov, Ya. A. Krutkov, Ye. L. Nikolai, and B. V. Bulgakov." Finally, in an introduction which is true to the (party) line, the invocation of the Five-Year Plan and the Communist Party could not be lacking. In the first chapter of the book general requirements for aeronautical equipment are discussed. In addition, structural parts, which are to appear again and again in many mechanisms, are discussed. In a very systematic form one finds here, for example, a tabular survey of 52 different measuring transmitters which, from time to time, are arranged according to input and output amplitudes. Exhaustive descriptions and designs of electrical and mechanical structural parts (potentiometers, inductive and capacitative transmitters, spring arrangement, dampers, etc) can be very valuable for designers.

The second and most extensive chapter of the book has detailed theoretical and descriptive designs of equipment for recording pressure, temperature, quantity and charge of fuel, number of revolutions, altitute, speeds and course deviations with magnetic means.

In the third chapter the most important gyroscope mechanisms are described in about 100 pages and the different automatic pilots are described in an additional 50 pages. It would be interesting to note the names of the most important Soviet researchers which are cited at the beginning (of the chapter): "The development of the fatherland's aeronautical gyroscope equipment is the service of the Soviet designers Ye. F. Antinov, Ye. V. Olman, V. Ye. Sorkin, and

others"... "The most important works concerning gyroscope theory
are by the well known Russian scientists N. Ye. Zhukovskiy,
A. N. Krylov, Ye. L. Nikolai, B. I. Kudrevitch and, concerning
applied gyroscope theory, B. V. Bulgakov. The development of the
theory of aeronautical gyroscope equipment came about through the
works of S. S. Tikhmenev, A. S. Koslov, Ya. I. Solovayev, G. O.
Friedländer, Ya. N. Roitenberg, P. V. Bromberg, V. A. Pavlov, and
others."

The turn-and-bank indicator is described as the first of the
gyroscope mechanisms. Two design forms are shown, of which the first
has a direct current gyroscope and is constructed essentially like
the Askania turn indicator; the second, however, is identical with
the turn-and-bank indicator brought out by the LGW firm around 1942,
in which a gyroscope of spherical shape ("the furious walnut") of
30-mm diameter was used as the rotor. The drawing used in this book
has been taken over without any change from an LGW prospectus. The
damping gyro, with whose help the rate of revolution and the rotary
acceleration can be measured at the same time, is described only in
brief and is illustrated in two drawings.

On the other hand, the different horizons are again treated
in detail. After a description of the most useful designs (Sperry),
we (find) used a general error theory of the horizon and reference
made to the possibilities of reducing above all the banking error.
For this purpose one can either switch off the traverse (power)
assistance during a banking turn or can, however, install the gyro
axis in the airplane somewhat inclined in the direction of flight.

A "yaw and roll gyroscope with proportional (power) assistance"
is described only briefly. Since for this purpose, however, the most
important data and also a photograph are given, one can assume with

safety that this relatively complex mechanism has actually been constructed. It is used, for example, in the automatic control as an indicator for banking turns and pitch. The whole mechanism weighs 8.3 kg and has external measurements of 200 x 263 x 215 mm.

The turn-and-bank indicator combined with artificial horizon which originated with the firm of Horn and which combined horizon, turn-and-bank indicator, and banking level in one housing has been reproduced in Russia. In any case, to a certain extent, considerable changes have been undertaken, for exaple, in the type of recording as well as in the adjustment. Moreover, the Russian gyroscopes work with a rate of revolution of 400 hz., while the German mechanism is is equipped with two 500-hz. gyroscopes. The (power) assistance of the horizon occurs through small mercury spirit levels which make contacts for certain inclinations. Migratory curves have been devised and mentioned in this book for an assistance of this type according to the "yes-no" principle and also for assistance characterized by hysteresis.

Next to the previously named conventional horizon types, the Russians have concerned themselves with the question of aerobatic horizons and have even built a mechanism of this type. However, the description is so incomplete that the principle of the mechanism cannot be clearly determined. In any case, it deals with a Cardan syspended horizon in which, however, the rotor axis is not vertical to the inner Cardan axis. In this manner they avoid the coincidence of rotor axis and external Cardan axis after a turn of 90 degrees around the inner Cardan axis; however, in this singular case the axes of the system still fall in a plane. The mechanism equipped with an alternating-current gyroscope weights about 2 kg and has external measurements of 126 x 189 x 132 mm.

The method of operation of another aerobatic horizon which
is, however, presented only as a diagrammatic sketch, is easy to see
through. In this case they have used a third Cardan ring in which
the external Cardan axis of the otherwise normal horizon system is
located. The additional Cardan ring is adjusted as usual and thus
will only be free when the gyroscope housing has turned 70 degrees
around the inner Cardan axis. The adjustment of the additional ring
will be switched on again if the rotary angle β of the gyroscope
housing leaves the range $70^{\circ} < \beta < 110^{\circ}$. In this manner the gyroscope
will be given an additional degree of freedom in the region of the
dangerous "clinch-position."

The section about the various horizons is concluded with a
short description of three different power-assisted artificial horizons
in which the gyroscope is only the sensitive element; the stabilizing
forces, however, of assistance motors are applied. Three simple
schematic sketches of such equipment (with 1,2 and 4 gyroscopes) are
shown, but there is no indication whether mechanisms of this type
have been built. The sketch of the arrangement with four gyroscopes
deviates from the power-assisted artificial horizon outlined by
Roitenberg in 1942 only to the extent that here the rotor axes are
all vertical to the plane of the stabilized platform, while the
original (Roitenberg) arrangement placed the gyroscopes so that
the rotor axes were parallel to the platform.

Also, in the discussion of the gyroscopic course indicator,
as in the discussion of horizons, after a short description of the
main possibilities, a general error theory is brought forth which
represents in a noteworthy and complete manner the errors (caused)
by the rotation of the earth, displacement of the center of gravity,

axial friction, Cardan suspension and by acceleration forces in various flight positions.

The above mentioned gyroscopic course indicator, which was already comprehensively reported on page 45, is here described in detail as the first mechanism. Here they are dealing with a gyroscopic course indicator with a magnetic assistance in which the magnet needle serving as sensitive element is located directly over the gyroscope in the mechanism housing. It is also worth noting in this construction that the assistance of the gyroscope system around the inner Cardan axis does not occur simply vertically to the plane of the external Cardan frame, but rather, vertical to the direction of the apparent perpendicular which is indicated -- as in the pneumatic Sperry horizon -- by two small regulatory pendulums. D. A. Braslavskiy, M. G. Elkind and M. M. Katchkatchian are named as designers of this mechanism.

[The Russians] have sought to avoid the disadvantages of the pneumatic mechanism with direct magnetic assistance by the further development that first of all one assumes a separation between course detectors and gyroscopes, secondly, that the mechanism is electrically operated and finally, thirdly, an induction compass is used in place of a magnetic needle. In order to get the necessary assistance currents for the gyroscope, an additional two-step tube amplifier is installed between the induction transmitter and the gyroscope. The mechanism thus produced is illustrated in detail by construction sketches and photographs.

On the other hand, a "gyroscope-induction-compass," which was already mentioned in Schlandin's book (P. 34) ▬▬, is treated in a relatively brief manner. They are dealing here with an induction compass in which the three induction coils, which are reset at each 120°, are mounted on an artificial horizon in order thus to remain constantly in the horizontal plane.

The mechanical possibility for assistance which was applied by Alkan -- that is, a rotating sphere on the gyroscope housing -- is mentioned quite briefly.

At the conclusion of the section on gyroscopes equipment, a "three-gyroscope-central," which can assume the job of horizon and gyroscopic course indicator at the same time, is once again described in brief. In this they are dealing with a fusion of three normal monoaxial power stabilizations which consist of one gyroscope each and one (power) assistance motor for each axis. A magnet compass is provided as a measuring gauge for the course axis while liquid spirit levels are provided for the other two axes. The controls for the assistance motors around the two transverse axes are calculated in this case in a special coordinate converter from the indicator values of the spirit level. Also, in the section about automatic pilots the names of the most important Soviet researchers are mentioned. In this section we read: "The questions of the dynamic stability of the airplane are explained not only theoretically but experimentally in the fundamental works of V.P. Vetchinkin, V. S. Vedrov, V. S. Psychnov, L. V. Klimenko, I. V. Ostoslavskiy, G. S. Kalatschev, and others. ... A number of successful constructions of automatic pilots were designed by the Soviet engineers I. A. Timofeyev, A. A. Lusis, M. F. Sediskiy, V. Ye. Sorkin, and others, in which the products of foreign firms were considerably surpassed. The engineers Ye. F. Antinov, Ye. V. Olman, L. I. Semenov and others have played a large part in the recent development of the construction of automatic pilots in the USSR.

After the presentation of theory for automatic pilots, which for the purpose of this book was fully sufficient, several designs are then described more closely. In this it is worthwhile to note

that the automatic pilots described in the book (37) are no longer

mentioned at all. One could therefore assume that they have since

been replaced by more recent designs. Also, the 3-axis automatic

pilot PGAP (abbreviation for "pneumatic-hydraulic automatic pilot")

which is next described in the book can again (be considered) as

having already been made obsolete. It still has the principal

structure which has been known since the old pneumatic Sperry

3-axis control. The horizon, however, had been somewhat redesigned.

Also the automatic pilot of EAP type (abbreviation for "electri-

cal automatic pilot") which was next described, has apparently not

been successful. It operates according to the same principle as

the previously mentioned automatic pilot and has as gyroscope

mechanism a horizon as well as a course indicator gyroscope. The

rigid circuit is rigidly formed so that when unidirectional moments

appear, certain residual errors will still remain.

The next described automatic pilot of type EAPB (abbreviation

for "electrical automatic pilot without rigid return circuit") has

been completely changed in the principle design and construction.

One can recognize without difficulty that the German 3-axis control

of Rechlin (Moeller) as well as the structural parts of IGW and Patin

were the sources in the design of the control A telecourse indicator

gyroscope assisted by a magnet needle serves as measuring transmitter

for the vertical axis of plane and also, for each of the three axes

an additional damping gyroscope which simultaneously dispenses with

the rate of revolution and the rotary acceleration. On the inner

Cardan axis of the horizon there is further mounted an additional

acceleration gauge which dispenses with the horizontal component

of the airplane's acceleration and operates as an additional controlling
entity for the longitudinal bearing. * The mixture of the individual
measuring values comes about -- as in the Patin mechanism -- through
highly receptive galvanometric systems with multiple input coils
and potentiometer tapping for the output. The telecompass, as well
as the horizon also, is used at the same time for the recording and
for this purpose is connected with corresponding "repeaters." Data
given for these automatic pilots is as follows:

Service altitude	12 km
Feed voltage	27 v $\pm$ 10%
Moment of steering engine	18 mkg
Maximum speed on drift bar	
of steering engine	70 mm/sec
Necessary power	500 w
Weight	75 kg
Admissible pitch angle	$\pm$ 85°
Admissible banking angle	$\pm$ 70°

* P.S. Besides the above-named measuring transmitters there is
also a Pitot tube whose recording value is likewise drawn
into the formation of the control values for the longitudinal
control.

REVIEW OF RUSSIAN WORKS ON APPLIED MATHEMATICS, MECHANICS, AND GYROSCOPICS

G. V. Shchipanov, Giroskopicheskiyepribory slepogo poleta. Teoriya,, raschet i metody konstruirovaniya [Gyroscopic Devices for Blind Flying. Theory, Computation, and Construction Methods], State Publishing House for the Defense Industry, Moscow-Leningrad, 423 pages, 6,000 copies.

According to the preface by the author, this book may be regarded as a sequel and supplement to a book by the same author entitled, "Theory, Computation, and Construction Methods of Aeronautical Devices." This book, covering blind-flying gyroscopic devices, consists of two parts. The first part deals with the "Special Theory of the Pendulum and Gyroscopic Directional Indicator" and allegedly gives the theoretical fundamentals on which the computation and construction are based. The second part of the book entitled "Gyro Compass, Artificial Horizon, and Turn Indicator" shows how the general theory is applied to special devices, whereby the author limits himself to the three aforementioned gyroscopic devices. Not one word is said in the entire book about the directional gyro, although at the time of the book's publication such a finished and tested device was already available.

The author does not mention in his introduction -- as is the usual procedure in Russian books -- for what group of readers the book was written. Better books are available for the theorist, for instance "Applied Gyro Theory" by Bulgakov which appeared two years before this book, or the book written by Krylov and Krutkov on "General Gyro Theory" which is still older. The theory offered in this case is, despite the many superfluous formulas which fill lots of pages, full of gaps and incomplete, and in many cases simply misleading. The book can hardly be recommended for designers since the unnecessary multitude of formulas only causes confusion. You cannot expect the designer to struggle through more than four hundred pages of obscure calculations and to find out in the end that the solution of the problem he wants is not found in the book. One concludes therefore that this voluminous book is redundant and without value. It could even be mentioned as having a damaging effect on the reader since without hesitation too much use has been made of approximations in the calculations and many of the drawings and sketches lack the necessary accuracy. Some of them are not only quantitatively wrong but simply qualitatively untrue.

The first part of the book covering close to two hundred pages and treating of "Special Theory", gives long-winded explanations on general problems of the theoretical mechanics, which can be found much better, clearer, and more concise in textbooks on theoretical mechanics. The manner of word usage also is very misleading. For example, the author uses the expressions of precession and nutation generally for the two natural frequencies of systems with two degrees of freedom. At another place the same nomenclature is used for two components of one and the same oscillation. The reader is spared nothing when the systems of two degrees of freedom are discussed. He has to endure all possible combinations of return, damping, and coupling terms in the linearly established two differential equations of the second degree. After reading about one hundred pages of this talk one will discover that an engineer well acquainted with theoretical mechanics could have come to this conclusion after reading a few pages. Thus the author finally arrives at two systems each consisting of two coupled linear differential equations which

only differ from each other in the type of the return terms. In the first
system indicated with an "S" (Sperry), the return forces are placed above
the cross in the differential equation system while in the second system,
indicated with an "A" (Anschüetz), the return forces for a coordinate also
are used for this coordinate in the differential equation. Later the author
discusses some intermediate forms of these systems of equations and indicates
them with "SA".

An approximation method, originally developed by Bairstov and was widely
and without hesitation used in the solution of equations of the fourth degree.

The theory of the gyrocompass as presented in the second part of the
book does not give us anything new as compared to what had been written by
Krylov and Krutkov or by Bulgakov. However, in spite of the wide scope, im-
portant parts of this theory, such as the pendulum error, are not discussed,
and only briefly mentioned.

The theory of the acceleration-free synchronization (eighty-four minute
principle) which is of fundamental importance, especially to the gyrocompass,
is discussed in a biased manner. After this came the theory on gyroscopic
horizons which is voluminous as well as incomplete. Again the author will
tire his reader with unnecessary generalities of his research in which he also
discusses the theory of systems which cannot be used in practice. Two devices
are discussed in detail; the Sperry gyro horizon and the gyro horizon of An-
schüetz and Co. While testing the two devices, the author ventures to predict
that the Anschüetz gyro horizon will in the future displace the Sperry instru-
ment especially if one thinks of the utilization of the gyro horizon in the
automatic pilot. The seventeen years since the publication of the book have
proved the opposite to be true.

During the discussion of the Sperry horizon it may be of interest to note
that it was tried without result to make the dimensions of the Sperry horizon
smaller, without decreasing its accuracy. It does not follow from the text,
however, where and how these tests were made. During the discussion of the
error theory of the Sperry horizon, one is startled to find that the maximum
error approximates the angle at which the control pendulums clear the exhaust
nozzles completely. This misleading result is no doubt caused by the fact
that the error theory actually forms the basis for the behavior with accelera-
ted rectilinear flight.

After enduring this theory of the gyro horizon one is not surprised at
the statement that the gyro really is not used at all, and that what you need
is to find the mechanism necessary to produce the terms in the differential
equations. The author does not reveal, however, how he plans to do that with-
out gyroscopes.

The theory of the turn-and-bank indicator, which actually forms the basis
for the devices made by "Pioneer" and "Schilowski", is kept entirely within
the framework of the gyro compass and horizon theories. For example, the
computation of the springs for holding down the frame is given with all the
details, as if there were no reference books for this type of computation, but
not a word is said about the stabilizer.

In this chapter you also find the presumptuous assumption that the indi-
cated method of computing not only can be used for Pioneer and Schilowski but
also for any other constructive variation of bank-and-turn indicators, which
may be conceived at all.

The last paragraph of the book, entitled "Construction Components, Se-
quence of the Computation, and Design of Gyroscopic Devices", is again noted

for the arrogant and unscrupulous manner in which the applied theory of gyroscopes is discussed in this book. Aside from the many things which were said before and are repeated again, a computation schedule is given for each of the devices under discussion from which the separate steps may be seen that have to be taken during the calculation. Since the formulas are given simultaneously with each step, actually you have an ideal "cookbook" in front of you with the help of which you can easily compute several compasses, horizons and bank-and-turn indicators on a weekly basis -- if the schedule were complete!

The schedule for the Sperry horizon contains, for instance, all data for the control pendulums as well as the air exhaust nozzles computed very accurately, but the only advice given for the computation of the rotor is: "Determine the dimensions of the rotor from the overall dimensions of the entire device". To determine the number of revolutions of the gyro the rule is simple: "Divide the obtained impulse by the moment inertia of the rotor!" The last of a total of twenty-five points of the plan to be followed in the computation of the Sperry horizon is called plainly and simply: "control and stress calculations" in which the necessary formulas of course were not included.

To sum up the opinion of the reviewer: The book is written in an arrogant and obscure manner; hence it is without value. A designer can get much farther with the help of a textbook on theoretical mechanics and an engineer's manual.

N. I. Chistyakov, <u>Elektricheskiye aviatsionnyye pribory</u> [Electrical Instruments for Aviation State Publishing House for the Defense Industry, Moscow, 1950, 534 pages, 6,000 copies, price 18 rubles.

In the preface of the book the author emphasizes that several good books are available in the field of mechanical aeronautical devices. However, no suitable textbook was available on electrical aeronautical devices which could be used in school for the training of aeronautical engineers. The book supposedly fills this gap. It has officially been introduced as a textbook.

The preface begins with the sentence: "Our country is the country of an enormous air force. Soviet airplanes fly and will always fly higher, faster, and farther than all other planes in the world."

The introduction begins with the sentence: "Electrical devices originated in our country. The famous Russian scientist M. V. Lomonosov built the first apparatus to measure electricity about 200 years ago."

Nearly all chapters of the book start with similar sworn statements and in regard to gyroscopic devices there is no exception: "All basic principles and ways of application of the gyroscope have been worked out in the USSR by many Russian scientists and engineers such as A. N. Krylov, B. V. Bulgakov, Ye. B. Lewenthal, Ya. N. Roitenberg, G. A. Slomyanskiy, Ya. I. Soloviyev, G. O. Friedlander, S. S. Tichmenev.

This does not prevent the author from showing a few pages later mostly pictures of foreign gyroscopic devices, without mentioning naturally the land of their origin. Only about seventy pages of this bulky book are devoted to electrical aeronautical devices. The author confines himself to descriptions of the design and the operational characteristics of the most important gyroscopic devices. In only a few cases computations and diagrams of component parts of gyroscopic devices are given; for instance, on the various types of electric supporting devices, consisting of an indicator and a torque producing unit. The various possiblities of servomechanisms are also discussed; however, usually well-known foreign designs are quoted. The general constructions of bank-and-turn indicators, gyro horizons, force supported gyroscopic frames is

only briefly described, but much room is devoted to the discussion of the gyrocompass. The Russian designers followed in this case their own initiative as can be seen from the descriptions. Again you will find a description of the directional gyro controlled by a magnetic needle, in which the magnetic needle has been fastened directly above the gyroscope in the housing of the device. This arrangement is later abandoned in favor of a foreign design which provides a spacious separation between the gyroscope and the magnetic needle.

Independent from the monitoring by means of magnetic needles, much work has been done in the field of induction selsyns, which are capable of indicating the direction of the earth's magnetic field. Two of these devices, both of which also use a gyroscope, have been built and tested. The gyroscope in the "horizontally balanced induction compass" serves only as a horizon in order to establish a proper basis for the induction coils. A directional gyro is not present in this case. The reading of the induction selsyn is directly transferred to an indicator by means of an amplifier. In the case of the "gyro induction compass" we have a supported directional gyro the monitoring of which is provided by the induction selsyn. In this case the induction selsyn takes only the place of the magnet of the "remote reading compass." This gyro induction compass is described in great detail even with some constructional features included. Pictures of the finished apparatus are included. In order to be able to utilize the output currents of the induction selsyn for the support of the gyroscope, these currents are conducted across a two-stage tube amplifier located directly in the housing of the directional gyro. It may be concluded from other remarks that the design did not stand up too well for they were trying to obtain a higher degree of safety of operation through a change in construction. The construction of this device should be such that it can still be used even if the amplifier breaks down. For that reason they went back again to the use of a magnetic needle system as an indicator but this time its rotations were transmitted to the course axis of the gyroscope by means of a "magnesynsystem." If deviations are present a corresponding supporting current is applied to the internal cardanic axle. In case the support fails the magnesyn can be switched directly to the indicator.

A course indicator operating with an electron beam is also described. The deflection of an electron beam is used to indicate various courses. The directional gyro can be monitored by means of amplifiers. During the development of this device they planned to produce an inertialess indication of the direction of the earth's magnetic field. However, since the same goal was reached in a much simpler manner by the use of the inductive method, the work on the electron beam course indicator lost its importance and has been discontinued for some years.

A description of the "automatic pilot", discussed in several other books, is given in chapter XIX. The device can automatically plot the route of an airplane on a chart from data supplied by course and airspeed indicators. Accordingly it also contains a directional gyro in addition to an airspeed indicator. A disadvantage of the design is that changes in wind direction during flight cannot be allowed for, and that a certain sensitivity is present as a result of fluctuations in the voltage supply.

The bibliography at the end of the book lists a total of eighty-two publications which for the most part cover topics of a purely electrical nature. All worthwhile information related to gyroscopic devices has been included in the bibliography of the main report.

> V. A. Pavlov, Aviatsionnyye giroskopicheskiye pribory [Aeronautical Gyroscopic Devices], State Publishing House for the Defense Industry, Moscow, 1954, 411 pages, price 12.85 rubles. (It is noteworthy that this publishing house no longer indicates the number of copies of the edition.)

This book may be considered the second edition of a book published in 1946, entitled: "Fundamentals of the Design of Gyroscopic Devices". It has been introduced as a textbook for the special field of "aeronautical devices" for advanced training in aeronautical schools. Apparently the author had given a course on gyroscopic devices for quite some time in such a school and finally published the material used in this course in book form in an amplified manner.

As compared to the first edition the number of pages of the book has almost doubled (411 as compared to the previous 223 pages); however, if the larger format is also considered, it has more than doubled. It may be noted that the price of the book has been lowered despite its greater size and that it is a considerably better publication. Through comparison of the tables of content it was determined that the increase in size actually can be traced to the fact that a description and the theory of special gyroscopic devices is given in a number of chapters (III to IX), which formerly were not included. The wider scope in other parts of the book can nearly without exception be explained by the wider and more detailed discussion of the theory -- as I am sorry to say! For the theory was already rather weak in the first edition, while part of the more practical sections are excellent. These practical sections, however, have been copied without much change.

The manner in which the theoretical fundamentals as well as the computation of some devices is done is typical of Russian textbooks. It is a decided "cookbook" type theory! Instead of discussing some important examples so as to clarify the methods of computation, every single case is again thoroughly calculated with all possible details. In other words a tiresome repetition is presented in all sections of the solutions of some differential equations with constant coefficients with sometimes small variations in initial conditions or in the single terms of the initial equations. It is difficult to conceive that all this material can be mastered within the scope of a course on aeronautical devices, as presented in this book.

It is obvious that this book is the work of a teacher of long standing, because a great number of rather good demonstration models are described and shown in pictures. The great number of exercises are evidence of an intensive instruction method.

The introduction contains some valuable references. The names of some designers are mentioned here who have distinguished themselves, especially in the development of gyroscopic devices. They are V. I. Kusnetsov, Ye. F. Antikov, S. F. Farmakoriskiy, and A. I. Markov; in another place in the book, D. A. Braslanskiy, M. M. Katschkatschian and M. G. Elkind, are mentioned as the designers of the directional gyro supported by a magnetic needle. Furthermore S. A. Nosdrovakiy is called the inventor of the force supported gyroscopic frame. In addition the same theorists are mentioned who are already sufficiently known from other publications.

Chapters I and II present the general theoretical fundamentals. Especially the influence of friction on bearings as well as the effects of the earth's rotation are examined. The gimbal rings are now also considered in the derivation of the general gyro equations, apparently according to the example of Nikolai. All other calculations, however, are based on the simplified linearized gyro equations.

The only point of interest in chapter III, which covers simple, nonsupported directional gyros, is the statement about two migration curves which were recorded with two different devices. The larger had an average migration of 10°/hour with a rotor weight of 700 grams, while the smaller with a rotor weight of 172 grams had a migration of 25°/hour.

In chapter IV you learn that the supported directional gyroscope as developed in the USSR in which the correcting magnetic needle is installed directly above the rotor in the housing of the device, has been abandoned in favor of the "telecompass'. The latter device, the design of which incorporates a separation between the gyroscope and the magnetic needle, has been described in detail with its various types of transmission. The Russian development appears in close support of previous German design. The "gyroscopic magnet", in which simply a magnetic needle is rigidly connected to a rotor housing, as proposed by Chochlov and appearing with a detailed calculation in a publication (number 29 of the bibliography), is mentioned by Pavlov as "interesting, but of impractical design."

Something new seems to be indicated by the possibility of keeping the directional gyro free from errors during certain aerobatic flight patterns. An arresting pin is installed in the gyro housing, which prevents the swinging through when rotating around the inside cardanic axis. Precession will cause the system to rotate rather rapidly around the outer axis until the inner ring is again released after a rotation of 180°.

Chapter V on the gyro compass is very detailed but of no importance. One is surprised to find it in this book at all, for it is specifically pointed out that the use of gyrocompasses in aircraft is not advisable because of their extensive weight and large course errors.

Chapter VI, dedicated to artificial horizons and verticals, included long descriptions and calculations for the many possible types of supports without showing or describing any definite devices. It may be of interest to point out here that the Soviets have picked up the original idea of Glitscher to obtain a compensation of error through the introduction of an artificial "drift to port". A diagram is shown in Figure 6.25 which looks exactly like a design by Glitscher. Whether such devices are actually being built cannot be deduced from the text.

Bank-and-turn indicators are discussed in Chapter VII. Actually it is a discussion of designs of German firms, some of which have been copied in the USSR. Something new in this chapter is the description of a bank and turn indicator, which lately in Russian literature is called "gyrotachometer", in which an increase in accuracy of indication is obtained by setting the reading always back to zero by means of shifting the zero point of the spring restrainer, which shift is then taken as a measure of the speed of rotation. It cannot be determined whether this device or any other gyroscopes for measuring velocity and acceleration described in this book have actually been built.

Chapter VIII mainly presents diagrams as well as some theory on a great variety of types of force supported gyro systems, also called inertia frames; however, no specific data on devices of this type are given.

Chapter IX contains a brief discussion on a position and angular velocity recorder for three components as developed by TsAGI, also an integrating and differentiating gyroscopic devices; finally a "gyro relay" and a "vector stabilizer" are mentioned of which the latter is used to determine the ground speed.

Chapters X up to XIV were taken from the first edition of the book with minor changes. The various component parts of gyroscopic devices such as rotors, bearings, supports, current transmission systems, and arresting equipment are discussed in these chapters.

The tables with rotor data taken from the first volume are here mainly

supplemented by the inclusion of smaller types of gyros. It is further found that the former German gyro types KA 4, KA 5, KA 7, as well as the LGW spherical gyro with a diameter of 30 mm (the so-called "mad walnut") are also included. One is of course somewhat surprised by the bold statement that this type gyro is an advanced development of one of the designs developed by the author (Pavlov). This "Pavlov gyro", of which even pictures are shown in an unassembled as well as assembled state appears to be very primitive; it consists of two halves of similar design, each provided with its own drive and coupled together with a pin. Each of the top-shaped halves has only one ball bearing, so that it is difficult to see how the system can operate sensibly.

This time smaller ball bearings have been considered in the chapter on supports and the tables have been supplemented accordingly. The latest results on the problem of friction in high-precision ball bearings (by Vieweg in Darmstadt) were evaluated, naturally without indicating the source!

The new edition also contains a small and incomplete sketch for an air-supported or liquid-supported gyroscopic device. After a poor description of only fourteen lines it says: "it should be pointed out that the type of support under discussion can only be used with gyroscopes having two degrees of freedom which remain stationary on the earth's surface. Despite a number of advantages of the described type of support, ball bearings are mainly used in aeronautical gyroscopic devices, because they have a longer life and also operate better in systems subjected to vibrations'."

Contrary to the poor information on air supports, you find again, as in the first edition, detailed information on various types of oscillating supports. Based on information found in this book it may be assumed with a high degree of probability that thorough investigation has been carried out in the USSR in connection with this problem. Numerical data on the values of friction obtained with various types of bearings show that with oscillating supports they still cannot approach the values as obtained with prismatic supports.

In the chapter on rotor bearings the Anschütz gyroscope bearing is discussed in detail.

Much practical material was assembled during the research on greatly different supporting devices. But also in this case preferably foreign designs were described. In a discussion on the support of the directional gyro by means of the earth's magnetic field, it was noticed that in addition to the established methods with the aid of magnetic needles or the induction compass, a device was described which operates with an electron beam. This device, developed by L. A. Gontscharskiy, A. P. Moltschanov, and V. K. Svorykin, utilizes the deflection of the beam of electrons caused by the earth's magnetic field to generate a supporting current.

The information and pictures on the problem of pneumatic support of the inside gimbal rings for the directional gyro are proof of the intensive work being done in this field. Measurements are made of the air pressure inside the gyro housing to determine the most favorable type of air conduit for the support. An electric support is recommended for larger gyros which will make it easier to obtain greater supporting moments.

The "Bulgakov Method" is used to determine the effect of supports with the gyro horizon.

The two chapters on power transmissions and arresting devices have been

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enlarged somewhat, but most of the descriptions discuss German designs.

Chapter XV entitled "How to Determine the Main Characteristics of Gyroscopic Devices" is a new chapter. After a brief description of various devices (three German designs as well as the three-component recorder developed by TsAGI), examples are given of calculations for all important gyroscopic devices and illustrated by means of numerical examples. It is possible that the teachers in the USSR have experienced such poor results with their teaching methods that by writing this type of "cookbook" they hope it may improve. You can find here all formulas if you want to compute "classic" gyroscopic devices, but in all other cases the book does not help. The warning directed by the author at the end of the chapter to the students that they cannot always follow this schedule to the letter probably will make the "cookbook engineers" more helpless.

Summarizing, it may be said that this new edition is very valuable, since plenty of material has been compiled in it. Unfortunately the important practical sections have hardly been supplemented while it would have been a pleasure to give up the insignificant theory.

V. V. Rumyantsev, "The Stability of the Spiral Motion of a Rigid Body in a Liquid under Conditions Specified by S. A. Chaplygin", Prikladnaya matematika i mekhanika [Applied Mathematics and Mechanics], Vol XIX, 1955, pages 229-230.

Chaplygin established the equations for the general motion of a rigid body in an infinitely expanded, ideal, incompressible liquid, and proved that in a special case four integrals of these equations can be estimated so that the problem can be reduced to a quadrature. Rumyantsev now indicates a special solution of the Chaplygin equations which corresponds to the case of a constant spiral motion of the body in the liquid. The stability of this spiral motion may now be found by examining the disturbed motion. The author forms a Liapunov function from three special integrals according to the example of Chaplygin from which then the stability conditions may be derived according to the well known requirements of definability. In the special case of a nonprogressive motion they are changed into the well-known stability conditions for the case as examined by S. V. Kovalevskiy.

P. V. Kharlamov, "An Integral Case of the Equations of Motion of the Heavy Rigid Body in a Liquid", Prikladnaya matematika i mekhanika [Applied Mathematics and Mechanics], Vol XIX, 1955, pages 231-233.

In connection with the research done by S. A. Chaplygin, a new case is presented in which the equation of motion for a rigid body located in an infinitely expanded ideal incompressible liquid can be integrated. In this particular case the center of gravity of the rigid body does not coincide with the center of gravity of the liquid mass displaced by it. Moreover, we are dealing here with a generalization of the well-known case of Lagrange, for which now a certain motion of propagation is allowed. The author succeeds in finding the solution of the angle of nutation and precession in the form of elliptic integrals. Then the author examines the stability of the motion found in this manner for a further simplified special case of this solution while determining a Liapunov function. The postulate of the definability of this function will give us the stability conditions we are looking for.

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